UNIT 2 Review

Knowledge/Understanding

Multiple Choice

In your notebook, choose the most correct answer for each of the following questions. Outline your reasons for your choice.

1. A hockey puck and a curling stone are at rest on a sheet of ice. If you apply equal impulses to each of them with a hockey stick
   (a) they will have the same acceleration
   (b) the forces applied were equal
   (c) they apply equal reaction forces to the hockey stick
   (d) they will have the same velocity, but different momenta
   (e) they will have the same momentum but different velocities
2. Ball B is moving and collides with a stationary ball A. After the collision, ball B bounces backwards with a velocity of nearly the same magnitude as it had before the collision. Ball A rolls forward very slowly. What is the relationship between the masses of the ball.
   (a) $m_A = m_B/2$
   (b) $m_A = 2\ m_B$
   (c) $m_A = 4\ m_B$
   (d) $m_A = m_B/4$
   (e) $m_A = m_B$
3. You throw a rock straight up into the air. While it rises and falls, its kinetic energy
   (a) remains constant
   (b) increases steadily
   (c) changes direction only
   (d) decreases then increases
   (e) increases then decreases
4. Starting from rest at the top of a hill, a bicyclist pedals furiously on the way down. The kinetic energy of the bicycle and rider at the bottom will be equal to
   (a) lost potential energy
   (b) work done
   (c) work done plus lost potential energy
   (d) work done plus kinetic energy plus potential energy
   (e) zero
5. An astronaut in an orbiting spacecraft is said to be weightless because
   (a) no force of gravity is exerted on the astronaut
   (b) the spacecraft exerts a force opposite to Earth's gravity and acts to suspend the astronaut
   (c) the astronaut and the spacecraft are both in free fall
   (d) the astronaut wears a special gravity-resistant spacesuit
   (e) there is no air resistance in the region where the astronaut is orbiting
6. A rocket launched with a velocity equal to the escape velocity of a planet has
   (a) positive total energy
   (b) negative total energy
   (c) zero total energy
   (d) a total energy that depends on its distance from the planet
   (e) a constantly changing total energy

Short Answer

7. If you throw a ball against a wall, which of the three impulses is the greatest: throw, bounce, or catch?
8. How is it possible for an object to obtain a larger impulse from a smaller force than from a larger force?
9. (a) Describe the differences between solving problems for elastic and inelastic collisions.
   (b) How can you tell whether a collision is elastic or not?
   (c) What happens to the kinetic energy of each object in an elastic collision?
10. Distinguish between an open system, a closed system, and an isolated system.
11. Explain why a water hose recoils when the water is turned on.
12. Explain why the first hill of a roller-coaster ride must be the highest hill.
13. (a) Under what conditions will a marble of mass m_1 and a rock of mass $3m_1$ have the same gravitational potential energy?
    (b) Under what conditions will a moving marble of mass m_1 and a moving rock of mass $3m_1$ have the same kinetic energy?
14. Write a general equation for the amount of mechanical energy in a system and include

expressions for as many different forms of potential energy as you can locate.

15. A physics wizard is sitting still, puzzling over a homework question. Provide an argument that she is not doing work in the physics sense. Provide a second argument that she *is* doing work in the physics sense.

16. Consider two bodies, A and B, moving in the same direction with the same kinetic energy. A has a mass twice that of B. If the same retarding force is applied to each, how will the stopping distances of the bodies compare?

17. **(a)** Under what circumstances does the work done on a system equal its change in kinetic energy only?
(b) Under what circumstances does the work done on a system equal the change in gravitational potential energy only?
(c) Under what circumstances does the change in kinetic energy of a system equal the change in gravitational potential energy?

18. Use the law of conservation of energy to discuss how the speed of an object changes while in an elliptical orbit.

Inquiry

19. The total momentum vector of a projectile is tangential to its path. This vector changes in magnitude and direction because of the action of an internal force (gravity).
(a) Sketch the path of a projectile and draw momentum vectors at several points along the path.
(b) The equation $\vec{F} = \Delta\vec{p}/\Delta t$ indicates that a change in momentum is evidence of a net force. Draw vectors that show the change in momentum at several points on the path and thus indicate the direction of the net force. (Neglect air resistance.) Discuss your result.

20. The law of conservation of energy can be written in the form $\Delta E = W + Q$, where ΔE is the change in energy in a system, W is the amount of useful work done, and Q is the amount of heat produced. In this form, it is called the "first law of thermodynamics." For centuries, crafty inventors have tried to violate the law by designing perpetual-motion machines. Such a machine would provide more energy as output than was input. The Canadian Patent Office has shown its faith in the law by refusing to grant patents for such machines based on design only. The inventor must submit a working model. Research and report on some designs for perpetual-motion machines. Include a sketch and use the first law of thermodynamics to discuss why the machine will not work.

21. Design a pogo stick for a child. Designate the age range of the child you hope will enjoy the stick and calculate the required spring constant. Determine other parameters, such as the length of the stick, the size of the spring, and the range of distances that the child will be able to depress the spring. Include a sketch of your design.

22. Insight into simple harmonic motion can be gained by contrasting it with non-simple harmonic motion.
(a) Consider the simple harmonic motion of an object oscillating on a spring. Does the velocity of the object change smoothly or abruptly when the object changes direction? Sketch a graph of the displacement of the object versus time.
(b) On the same graph, indicate how the spring force changes with time. Are the restoring force and displacement ever zero at the same time?
(c) Now consider the motion of a highly elastic rubber ball bouncing up and down on an elastic steel plate, always returning to the same height from which it fell. Set a frame of reference so that you can describe the ball's motion. Does the ball's velocity change smoothly or abruptly at its peak altitude and during impact? Sketch a graph of the displacement of the ball versus time.
(d) Draw a free-body diagram of the forces acting on the ball when it is in the air. What is the net force on the ball during contact with the steel plate? Are the net force and

displacement ever zero at the same time? On the same graph as (c), sketch how the net force on the ball changes with time.

(e) Contrast the two graphs in terms of the motions they represent.

23. In this question, you will use the kinetic theory of gases to probe the compositions of the atmospheres of four bodies in the solar system. The kinetic theory of gases can be used to relate the average kinetic energy of the molecules in a gas to the temperature, T, of the gas, $E_{k(\text{average})} = \frac{1}{2} m v^2_{\text{average}} = \frac{3}{2} kT$, where m is the mass of the molecule and k is the Boltzmann constant.

(a) Calculate the escape velocities of Jupiter, Mars, Earth, and the Moon.

(b) In a table of atomic masses, look up the masses for the following molecules: hydrogen (H_2), helium (He), water vapour (H_2O), methane (CH_4), oxygen (O_2), nitrogen (N_2), and carbon dioxide (CO_2).

(c) Calculate the average speed of each of the above gases of molecules at a temperature of 300.0 K.

(d) Some models of velocity distributions of gases indicate that over the lifetime of the solar system (approximately 5 billion years), a gas will escape from a planet unless its average speed times 10.0 ($v_{\text{average}} \times 100$) is less than the escape velocity of the planet. Use this to determine which gases should be present in each of the atmospheres in (a). (The velocity distribution of a gas is described as a Maxwellian velocity distribution — look up this term for further information.)

(e) Compare your results to observations.

(f) Summarize and discuss your results.

24. The orbit of a satellite is often used to determine the mass of the planet or star that it is orbiting. How can the mass of a satellite be determined?

25. Explain whether you could put a satellite in an orbit that kept it stationary over the North or South Pole.

26. Imagine that you found a very unusual spring that did not obey Hooke's law. In fact, you performed experiments on the spring and discovered that the restoring force was proportional to the square distance that the spring was stretched or compressed from its equilibrium or $F = -kx^2$.

(a) Describe an experiment that you might have done to find the expression for the restoring force.

Communication

27. To bunt a baseball effectively, at the instant the ball strikes the bat, the batter moves the bat in the same direction as the moving baseball. Explain what effect this action has.

28. You drop a dish from the table. Explain whether the impulse will be less if the dish lands on a carpet instead of a bare floor.

29. Explain whether it is possible to exert a force and yet not cause a change in kinetic energy.

30. You blow up a balloon and release the open end, causing the balloon to fly around the room as the air is rapidly exhausted. What exerts the force that causes the balloon to accelerate?

31. A jet engine intakes air in the front and mixes it with fuel. The mixture burns and is exhausted from the rear of the engine. Use the concept of momentum to explain how this process results in a force on the airplane that is directed forward.

32. Explain the difference between g and G.

Making Connections

33. When Robert Goddard first proposed sending a rocket to the Moon early in the twentieth century, he was ridiculed in the newspapers. People thought that the rocket would have nothing to push against in the vacuum of space and therefore could not move.

(a) How does a rocket move?

(b) Contrast the rocket's motion with the motion produced by a propeller or a wheel.

(c) A rocket can be considered to represent a case of the inverse of an inelastic collision. Explain this statement.

(d) Develop three analogies that could help explain rocket motion.

(e) To test his idea, Goddard set up a pistol in a bell jar from which the air had been evacuated and fired a blank cartridge. What do you think happened?

34. Analyze any appliance or technical device in terms of its component parts and the energy it consumes. Trace the path of this energy in detail backward through its various forms. How many steps does it typically take before you get to the Sun as the ultimate source of energy?

35. A Foucault pendulum can be used to demonstrate that Earth is rotating. Explain how this is possible. What differences would you notice if you used the pendulum at the North Pole, at Earth's equator, and at latitudes between these two points?

36. Before nuclear energy was postulated as the source of energy for the Sun, other energy-generation processes were considered. At the end of the nineteenth century, one promising method was proposed by Lord Kelvin. It was based on the perfect gas law: If a gas is compressed, it heats up. Heating the gas causes it to radiate energy away, so the gas can be further compressed. The process, gravitational contraction, is now thought to heat protostars (newly forming stars) before they begin nuclear fusion in their cores. Research this process and describe in detail how it could heat a star. How is gravitational potential energy converted into heat? What lifetime did this process predict for the Sun? Also, discuss how Darwin's theory of evolution led astronomers to believe that the lifetime for the Sun predicted by this process was too short.

Problems for Understanding

37. A 1400 kg car travels north at 25 m/s. What is its momentum?

38. What impulse is needed to stop the following?
   (a) 150 g baseball travelling at 44 m/s
   (b) 5.0 kg bowling ball travelling at 8.0 m/s
   (c) 1200 kg car rolling forward at 2.5 m/s

39. A 0.80 kg ball travelling at 12 m/s[N] strikes a wall and rebounds at 9.5 m/s[S]. The impact lasts 0.065 s.
   (a) What was the initial momentum of the ball?
   (b) What was the change of momentum of the ball?
   (c) What was the impulse on the wall?
   (d) What was the average force acting on the wall?
   (e) What was the average force acting on the ball?

40. A tennis player smashes a serve so that the racquet is in contact with the ball for 0.055 s, giving it an impulse of 2.5 N·s.
   (a) What average force was applied during this time?
   (b) Assume that the vertical motion of the ball can be ignored. If the ball's mass is 0.060 kg, what will be the ball's horizontal velocity?

41. A hockey player gives a stationary 175 g hockey puck an impulse of 6.3 N·s. At what velocity will the puck move toward the goal?

42. A 550 kg car travelling at 24.0 m/s[E] collides head-on with a 680 kg pickup truck. Both vehicles come to a complete stop on impact.
   (a) What is the momentum of the car before the collision?
   (b) What is the change in the car's momentum?
   (c) What is the change in the truck's momentum?
   (d) What is the velocity of the truck before the collision?

43. A rocket is travelling 160 m/s[forward] in outer space. It has a mass of 750 kg, which includes 130 kg of fuel. Burning all of the fuel produces an impulse of 41 600 N·s. What is the new velocity of the rocket?

44. A 19.0 kg curling stone for Team Ontario travels at 3.0 m/s[N] down the centre line of the ice toward an opponent's stone that is at rest. It strikes the opponent's stone and rolls off to the side with a velocity of 1.8 m/s[N22°W]. The opponent's stone moves in a northeasterly direction. What is the final velocity (magnitude and direction) of the opponent's stone?

45. Two balls collide on a horizontal, frictionless table. Ball A has a mass of 0.175 kg and is travelling at 1.20 m/s[E40°S]. Ball B has a mass of 0.225 kg and is travelling at 0.68 m/s[E]. The velocity of ball B after the collision is 0.93 m/s[E37°S].

(a) What is the velocity (magnitude and direction) of ball A after the collision?
(b) What percentage of kinetic energy is lost in the collision?

46. An 8.0 kg stone falls off a 10.0 m cliff.
(a) How much work is done on it by the gravitational force?
(b) How much gravitational potential energy does it lose?

47. Each minute, approximately 5×10^8 kg of water flow over Niagara Falls. The average height of the falls is 65 m.
(a) What is the gravitational potential energy of the water flow?
(b) How much power (in W or J/s) can this water flow generate?

48. A 0.250 kg ball is thrown straight upward with an initial velocity of 38 m/s. If air friction is ignored, calculate the
(a) height of the ball when its speed is 12 m/s
(b) height to which the ball rises before falling
(c) How would your answers to (a) and (b) change if you repeated the exercise with a ball twice as massive?

49. You are in a 1400 kg car, coasting down a 25˚ slope. When the car's speed is 15 m/s, you apply the brakes. If the car is to stop after travelling 75 m, what constant force (parallel to the road) must be applied?

50. An archery string has a spring constant of 1.9×10^2 N/m. By how much does its elastic potential energy increase if it is stretched (a) 5.0 cm and (b) 71.0 cm?

51. You exert 72 N to compress a spring with a spring constant of 225 N/m a certain distance.
(a) What distance is the spring displaced?
(b) What is the elastic potential energy of the displaced spring?

52. A 2.50 kg mass is attached to one end of a spring on a horizontal, frictionless surface. The other end of the spring is attached to one end of a spring is attached to a solid wall. The spring has a spring constant of 75.0 N/m. The spring is stretched to 25.0 cm from its equilibrium point and released.
(a) What is the total energy of the mass-spring system?
(b) What is the velocity of the mass when it passes the equilibrium position?
(c) What is the elastic potential energy stored in the spring when the mass passes a point that is 15.0 cm from its equilibrium position?
(d) What is the velocity of the spring when it passes a point that is 15.0 cm from its equilibrium position?

53. A 275 g ball is resting on top of a spring that is mounted to the floor. You exert a force of 325 N on the ball and it compresses the spring 44.5 cm. If you release the ball from that position, how high, above the equilibrium position of the spring-ball system will the ball rise?

54. A 186 kg cart is released at the top of a hill.
(a) How much gravitational potential energy is lost after it descends through a vertical height of 8.0 m?
(b) If the amount of friction acting on the cart is negligible, determine the kinetic energy and the speed of the cart after it has descended through a vertical height of 8.0 m.
(c) Explain what variables you would need to know in order to calculate the kinetic energy and the speed of the cart for the same conditions if the frictional forces were significant. Assume some reasonable values and make calculations for the kinetic energy and the speed of the cart influenced by friction.

55. A small 95 g toy consists of a piece of plastic attached to a spring with a spring constant of 365 N/m. You compress the spring against the floor through a displacement of 5.5 cm, then release the toy. How fast is it travelling when it rises to a height of 10.0 cm?

56. Suppose a 1.5 kg block of wood is slid along a floor and it compresses a spring that is attached horizontally to a wall. The spring constant is 555 N/m and the block of wood is travelling 9.0 m/s when it hits the spring. Assume that the floor is frictionless and the spring is ideal.
(a) By how much does the block of wood compress the spring?

(b) If the block of wood attaches to the spring so that the system then oscillates back and forth, what will be the amplitude of the oscillation?

57. A spring with a spring constant of 120 N/m is stretched 5.0 cm from its rest position.
(a) Calculate the average force applied.
(b) Calculate the work done.
(c) If the spring is then stretched from its 5.0 cm position to 8.0 cm, calculate the work done.
(d) Sketch a graph of the applied force versus the spring displacement to show the extension of the spring. Explain how you can determine the amount of work done by analyzing the graph.

58. A 32.0 kg child descends a slide 4.00 m high. She reaches the bottom with a speed of 2.40 m/s. Was the mechanical energy conserved? Explain your reasoning and identify the energy transformations involved.

59. A 2.5 kg wooden block slides from rest down an inclined plane that makes an angle of 30° with the horizontal.
(a) If the plane is frictionless, what is the speed of the block after slipping a distance of 2.0 m?
(b) If the plane has a coefficient of kinetic friction of 0.20, what is the speed of the block after slipping a distance of 2.0 m?

60. (a) Given Earth's radius (6.38×10^6 m) and mass (5.98×10^{24} kg), calculate the escape velocity from Earth's surface.
(b) What is the escape velocity for a satellite orbiting Earth a distance of 2.00 Earth radii from Earth's centre?
(c) How far away do you have to travel from Earth so that the escape velocity at that point is 1% of the escape velocity at Earth's surface? Answer in metres and in Earth radii.

61. A projectile fired vertically from Earth with an initial velocity v reaches a maximum height of 4800 km. Neglecting air friction, what was its initial velocity?

62. An amateur astronomer discovers two new comets with his backyard telescope. If one comet is moving at 38 km/s as it crosses Earth's orbit on its way toward the Sun and the other at 47 km/s, calculate whether each orbit is bound or not.

63. You want to launch a satellite into a circular orbit at an altitude of 16 000 km (above Earth's surface). What orbital speed will it have? What launch speed will be required?

64. In a joint international effort, two rockets are launched from Earth's surface. One has an initial velocity of 13 km/s and the other 19 km/s. How fast is each moving when it crosses the Moon's orbit (3.84×10^8 m)?

65. A 460 kg satellite is launched into a circular orbit and attains an orbital altitude of 850 km above Earth's surface. Calculate the
(a) kinetic energy of the satellite
(b) total energy of the satellite
(c) period of the satellite
(d) binding energy of the satellite
(e) additional energy and speed required for the satellite to escape

66. (a) Calculate the gravitational potential energy of the Earth-Moon system. (Assume that their mean separation is 3.84×10^8 m.)
(b) Calculate the gravitational potential energy of the Earth-Sun system. (Assume that their mean separation is 1.49×10^{11} m.)

67. Proposals for dealing with radioactive waste include shooting it into the Sun. Consider a waste container that is simply dropped from rest in the vicinity of Earth's orbit. With what speed will it hit the Sun?

COURSE CHALLENGE

Scanning Technologies: Today and Tomorrow

Consider the following as you continue to build your Course Challenge research portfolio.

- Add important concepts, equations, interesting and disputed facts, and diagrams from this unit.
- Review the information you have gathered in preparation for the end-of-course presentation. Consider any new findings to see if you want to change the focus of your project.
- Scan magazines, newspapers, and the Internet for interesting information to enhance your project.